

DATA SHEET

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**TL431C, TL431AC, TL431I,
TL431AI, LM431AC**

Adjustable precision shunt regulators

Product specification

1997 Feb 25

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

DESCRIPTION

The TL431 and TL431A are 3-terminal adjustable shunt regulators with specified thermal stability over applicable automotive and commercial temperature ranges. The output voltage may be set to any value between V_{REF} (approximately 2.5V) and 36V with two external resistors (see Figure 4). These devices have a typical output impedance of 0.2Ω . Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes in many applications like on-board regulation, adjustable power supplies and switching power supplies.

The TL431C and TL431AC are characterized for operation from 0°C to $+70^{\circ}\text{C}$; the TL431I and TL431AI are characterized for operation from -40°C to $+85^{\circ}\text{C}$.

FEATURES

- Equivalent full-range temperature coefficient: $30\text{ppm}/^{\circ}\text{C}$
- 0.2Ω typical output impedance
- Sink current capability: 1mA to 100mA
- Low output noise
- Adjustable output voltage: V_{REF} to 36V

PIN CONFIGURATIONS

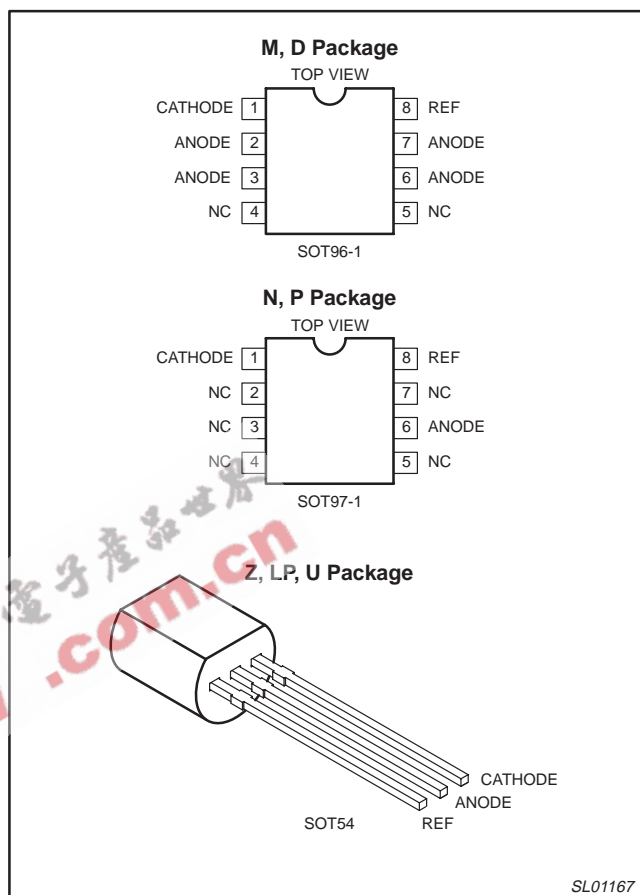


Figure 1. Pin Configuration

ORDERING INFORMATION

| DESCRIPTION | TEMPERATURE RANGE | INDUSTRY STANDARD PART NUMBER | ORDER CODE | DWG # |
|--|--|-------------------------------|------------|---------|
| 3-Pin Plastic TO92 ² | 0°C to $+70^{\circ}\text{C}$ | TL431CLP | TL431CLPU | SOT54 |
| 3-Pin Plastic TO92 ² | 0°C to $+70^{\circ}\text{C}$ | TL431ACLP | TL431ACLPU | SOT54 |
| 3-Pin Plastic TO92 ² | -40°C to $+85^{\circ}\text{C}$ | TL431ILP | TL431ILPU | SOT54 |
| 3-Pin Plastic TO92 ² | -40°C to $+85^{\circ}\text{C}$ | TL431AILP | TL431AILPU | SOT54 |
| 3-Pin Plastic TO92 ² | 0°C to $+70^{\circ}\text{C}$ | LM431ACZ | LM431ACZU | SOT54 |
| 8-Pin Plastic Small Outline (SO) package | 0°C to $+70^{\circ}\text{C}$ | TL431CD | TL431CD | SOT96-1 |
| 8-Pin Plastic Small Outline (SO) package | -40°C to $+85^{\circ}\text{C}$ | TL431ID | TL431ID | SOT96-1 |
| 8-Pin Plastic Small Outline (SO) package | 0°C to $+70^{\circ}\text{C}$ | TL431ACD | TL431ACD | SOT96-1 |
| 8-Pin Plastic Small Outline (SO) package | -40°C to $+85^{\circ}\text{C}$ | TL431AID | TL431AID | SOT96-1 |
| 8-Pin Plastic Small Outline (SO) package | 0°C to $+70^{\circ}\text{C}$ | LM431ACM | LM431ACMD | SOT96-1 |
| 8-Pin Plastic Dual In-Line package (DIP) | 0°C to $+70^{\circ}\text{C}$ | TL431CP | TL431CPN | SOT97-1 |
| 8-Pin Plastic Dual In-Line package (DIP) | -40°C to $+85^{\circ}\text{C}$ | TL431IP | TL431IPN | SOT97-1 |
| 8-Pin Plastic Dual In-Line package (DIP) | 0°C to $+70^{\circ}\text{C}$ | TL431ACP | TL431ACPN | SOT97-1 |
| 8-Pin Plastic Dual In-Line package (DIP) | -40°C to $+85^{\circ}\text{C}$ | TL431AIP | TL431AIPN | SOT97-1 |

NOTE:

1. SYMBOL INFORMATION: Parts will be marked with product name including temperature and electrical grade designators, but not the package identifier.
2. TO92 is normally shipped in bulk, i.e., in plastic bags (containing 1,000 parts), 5 bags per box. Tape and reel (or ammo box) is an option. See page 15 for information.

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ABSOLUTE MAXIMUM RATINGS

| SYMBOL | PARAMETER | RATING | UNITS |
|-----------|---|--------------|-------|
| V_{KA} | Cathode voltage (see Note 1) | 37 | V |
| | Continuous cathode current range | -100 to +150 | mA |
| | Reference input current range | 0.05 to 10 | mA |
| T_{amb} | Operating free-air temperature range C suffix I suffix | 0 to +70 | °C |
| | | -40 to +85 | °C |
| T_{STG} | Temperature storage range | -65 to 150 | °C |
| | Lead temperature 1.6mm (1/16 in.) from case for 10 sec: D or P pkgs | 260 | °C |
| | Lead temperature 1.6mm (1/16 in.) from case for 60 sec: LP pkg | 300 | °C |

NOTE:

1. Voltage values are with respect to the anode terminal unless otherwise noted.

RECOMMENDED OPERATING CONDITIONS

| SYMBOL | PARAMETER | MIN | MAX | UNITS |
|----------|-----------------|-----------|-----|-------|
| V_{KA} | Cathode voltage | V_{REF} | 36 | V |
| I_K | Cathode current | 1 | 100 | mA |

Table 1. Dissipation Rating Table – Free-Air Temperature

| Package | Derating Factor Above $T_{amb} = 25^\circ\text{C}$ | $T_{amb} = 25^\circ\text{C}$ Power Rating | $T_{amb} = 70^\circ\text{C}$ Power Rating | $T_{amb} = 85^\circ\text{C}$ Power Rating |
|---------|--|--|--|--|
| D | 5.8mW/°C | 725mW | 464mW | 429mW |
| LP | 6.2mW/°C | 775mW | 496mW | 403mW |
| P | 8.0mW/°C | 1000mW | 640mW | 520mW |

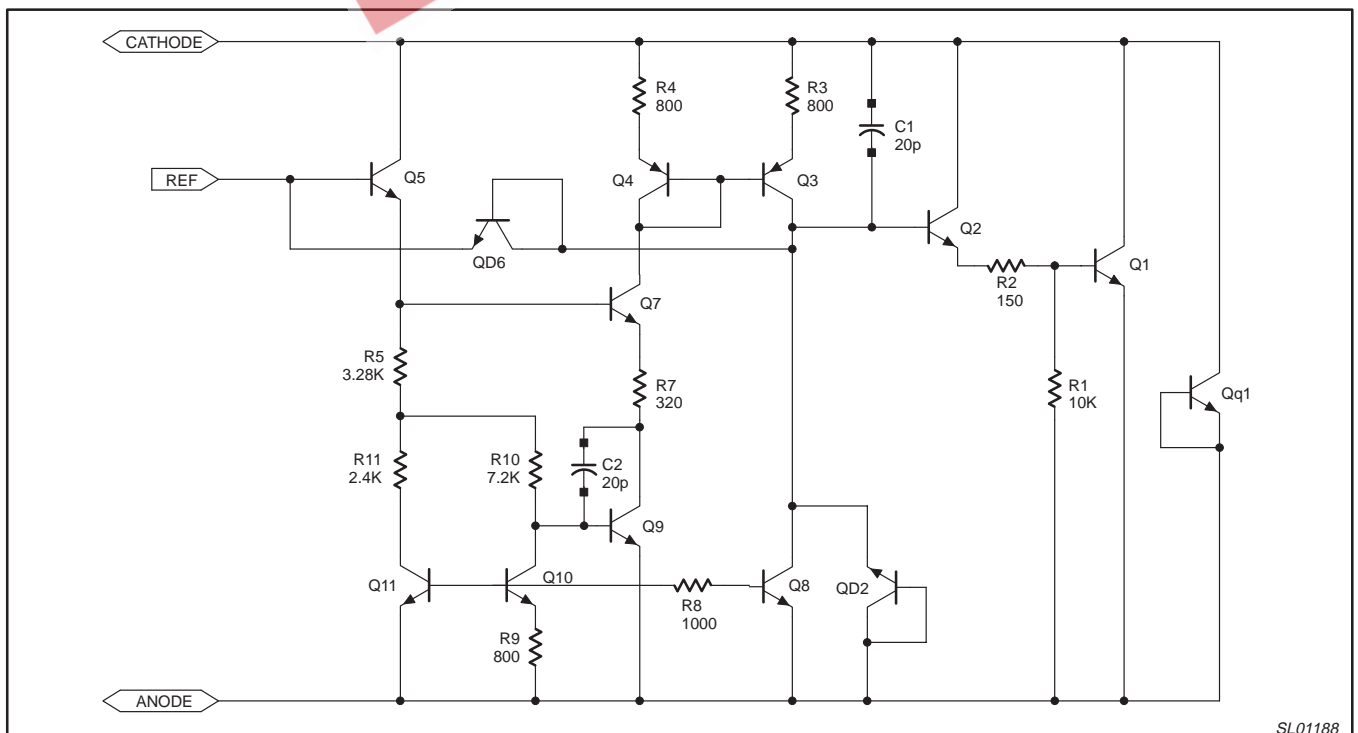


Figure 2. Equivalent Schematic

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I, TL431AI, LM431AC

DC ELECTRICAL CHARACTERISTICS

25°C free-air temperature, unless otherwise stated.

| SYMBOL | PARAMETER | TEST CKT | TEST CONDITIONS | LIMITS | | | | | | UNIT |
|--|---|----------|--|---|------|------|----------------|------|------|------|
| | | | | TL431AC | | | TL431C/LM431AC | | | |
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{REF} | Reference input voltage | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA | 2470 | 2495 | 2520 | 2440 | 2495 | 2550 | mV |
| V _{REF(dev)} | Deviation of reference input voltage over full temperature range ³ | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA, T _{amb} = full range ² | | 4 | 15 | | 4 | 17 | mV |
| $\frac{\Delta V_{REF}}{\Delta V_{KA}}$ | Ratio of change in reference input voltage to the change in cathode voltage | Fig. 4 | I _K = 10mA | ΔV _{KA} = 10V – V _{REF} | -1.4 | -2.7 | | -1.4 | -2.7 | mV/V |
| | | | | ΔV _{KA} = 36V – 10V | -1 | -2 | | -1 | -2 | |
| I _{REF} | Reference input current | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞ | | 2 | 4 | | 2 | 4 | μA |
| I _{REF(dev)} | Deviation of reference input current over full temperature range ³ | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞, T _{amb} = full range ² | | 0.8 | 1.2 | | 0.4 | 1.2 | μA |
| I _{MIN} | Minimum cathode current for regulation | Fig. 3 | V _{KA} = V _{REF} | | 0.4 | 0.6 | | 0.4 | 1 | mA |
| I _{OFF} | Off-state cathode current | Fig. 5 | V _{KA} = 36V, V _{REF} = 0 | | 0.1 | 0.5 | | 0.1 | 1 | μA |
| Z _{KA} | Dynamic impedance ⁴ | Fig. 3 | V _{KA} = V _{REF} , I _K = 1mA to 100mA, f ≤ 1kHz | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

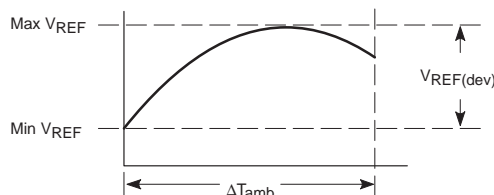
25°C free-air temperature, unless otherwise stated.

| SYMBOL | PARAMETER | TEST CKT | TEST CONDITIONS | LIMITS | | | | | | UNIT |
|--|---|----------|--|---|------|------|--------|------|------|------|
| | | | | TL431AI | | | TL431I | | | |
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| V _{REF} | Reference input voltage | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA | 2470 | 2495 | 2520 | 2440 | 2495 | 2550 | mV |
| V _{REF(dev)} | Deviation of reference input voltage over full temperature range ³ | Fig. 3 | V _{KA} = V _{REF} , I _K = 10mA, T _{amb} = full range ² | | 5 | 25 | | 5 | 30 | mV |
| $\frac{\Delta V_{REF}}{\Delta V_{KA}}$ | Ratio of change in reference input voltage to the change in cathode voltage | Fig. 4 | I _K = 10mA | ΔV _{KA} = 10V – V _{REF} | -1.4 | -2.7 | | -1.4 | -2.7 | mV/V |
| | | | | ΔV _{KA} = 36V – 10V | -1 | -2 | | -1 | -2 | |
| I _{REF} | Reference input current | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞ | | 2 | 4 | | 2 | 4 | μA |
| I _{REF(dev)} | Deviation of reference input current over full temperature range ³ | Fig. 4 | I _K = 10mA, R ₁ = 10kΩ, R ₂ = ∞, T _{amb} = full range ² | | 0.8 | 2.5 | | 0.8 | 2.5 | μA |
| I _{MIN} | Minimum cathode current for regulation | Fig. 3 | V _{KA} = V _{REF} | | 0.4 | 0.7 | | 0.4 | 1 | μA |
| I _{OFF} | Off-state cathode current | Fig. 5 | V _{KA} = 36V, V _{REF} = 0 | | 0.1 | 0.5 | | 0.1 | 1 | μA |
| Z _{KA} | Dynamic impedance ⁴ | Fig. 3 | V _{KA} = V _{REF} , I _K = 1mA to 100mA, f ≤ 1kHz | | 0.2 | 0.5 | | 0.2 | 0.5 | Ω |

NOTES:

- Full temperature range is -40°C to +85°C for the TL431I and TL431AI, and 0°C to +70°C for the TL431C and TL431AC.
- The deviation parameters V_{REF(dev)} and I_{REF(dev)} are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage, αV_{REF}, is defined as:

$$|\alpha V_{REF}| \left(\frac{\text{ppm}}{\text{deg C}} \right) = \frac{\left(\frac{V_{REF(dev)}}{V_{REF \text{ at } 25^\circ\text{C}}} \right) \cdot 10^6}{\Delta T_{amb}}$$



where ΔT_{amb} is the rated operating free-air temperature range of the device.

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αV_{REF} can be positive or negative depending on whether minimum V_{REF} or maximum V_{REF} , respectively, occurs at the lower temperature. Example: Max $V_{REF} = 2496\text{mV}$ at 30°C , Min $V_{REF} = 2492\text{mV}$ at 0°C , $V_{REF} = 2495\text{mV}$ at 25°C , $DTA = 70^\circ\text{C}$ for TL431C.

$$|\alpha V_{REF}| = \frac{\left(\frac{4\text{mV}}{2495\text{mV}}\right) \cdot 10^6}{70^\circ\text{C}} = 23\text{ppm}/^\circ\text{C}$$

Because minimum V_{REF} occurs at the lower temperature, the coefficient is positive.

4. The dynamic impedance is defined as: $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors, (see Figure xx), the total dynamic impedance of the circuit is given by:

$$|Z'| = \frac{\Delta V}{\Delta I} \approx |Z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

PARAMETER MEASUREMENT INFORMATION

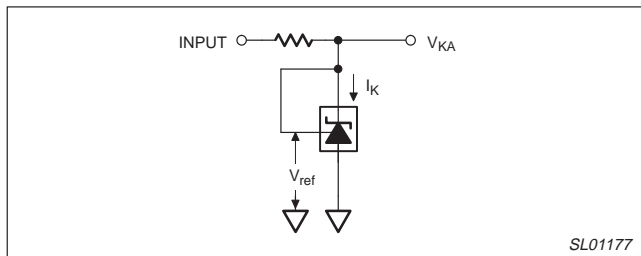


Figure 3. Test Circuit for $V_{KA} = V_{ref}$

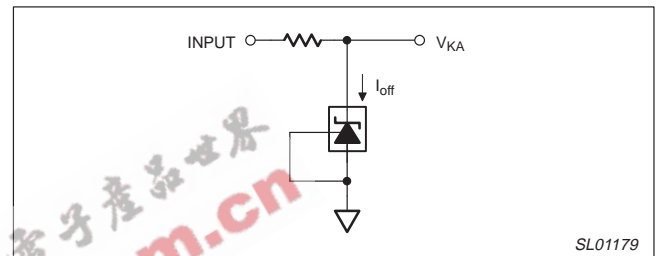


Figure 5. Test Circuit for I_{OFF}

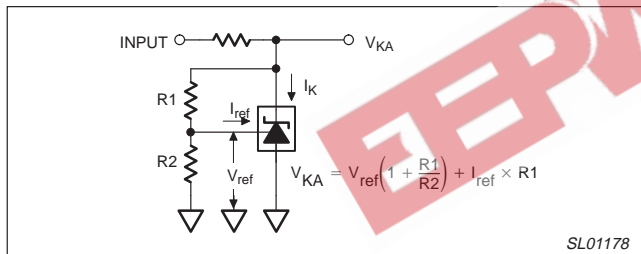


Figure 4. Test Circuit for $V_{KA} > V_{ref}$

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TL431AI, LM431AC

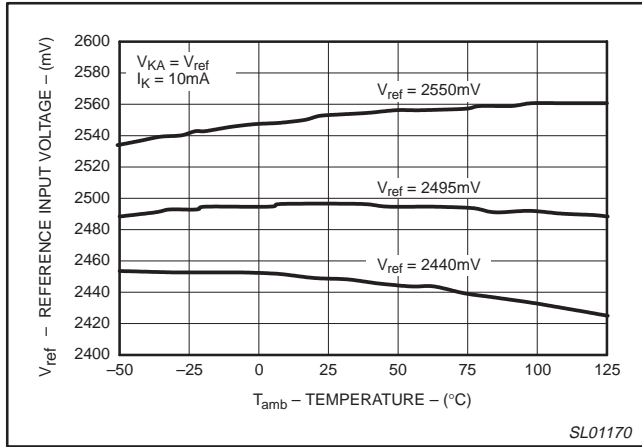


Figure 6. Reference Input Voltage vs. Temperature

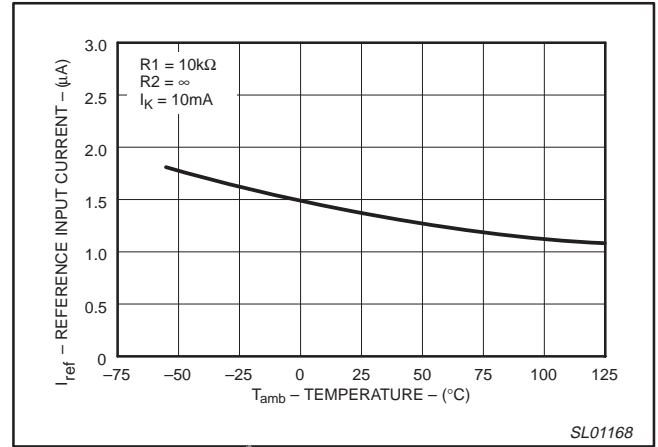


Figure 9. Reference Input Current vs. Temperature

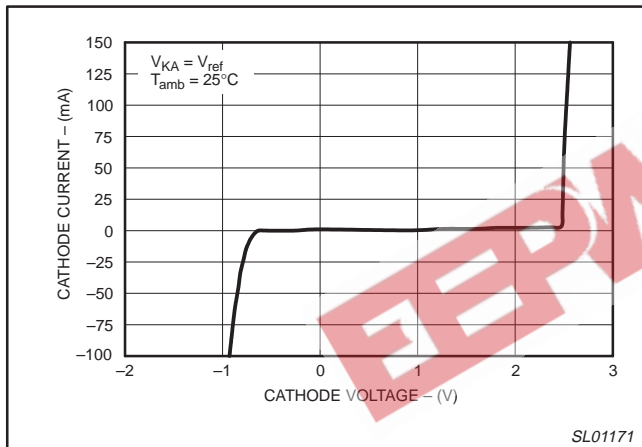


Figure 7. Cathode Current vs. Cathode Voltage

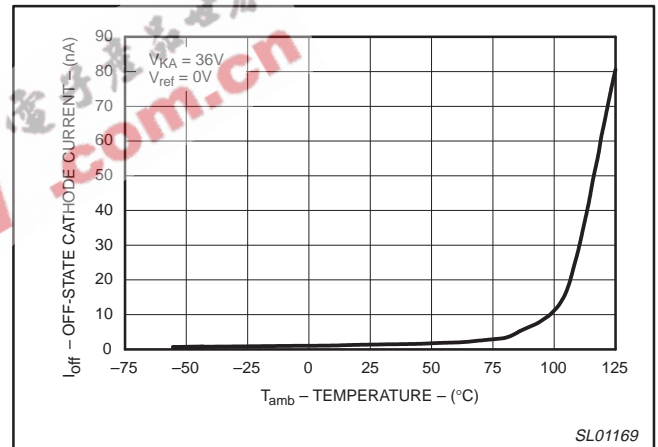


Figure 10. Off-State Cathode Current vs. Temperature

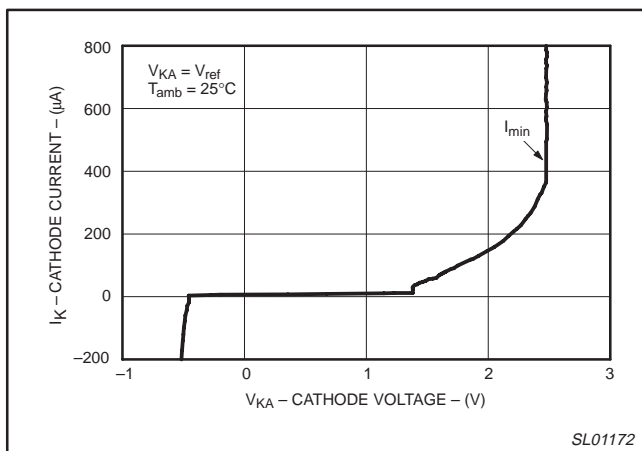


Figure 8. Cathode Current vs. Cathode Voltage

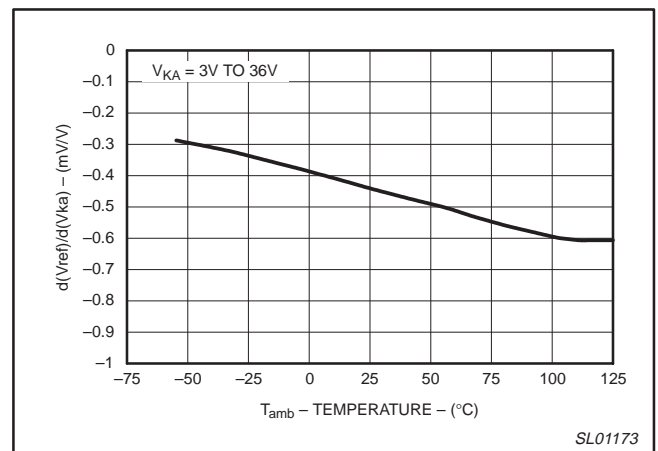


Figure 11. Ratio of Delta Reference Voltage to Delta Cathode Voltage over Temperature

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TL431C, TL431AC, TL431I,
TL431AI, LM431AC

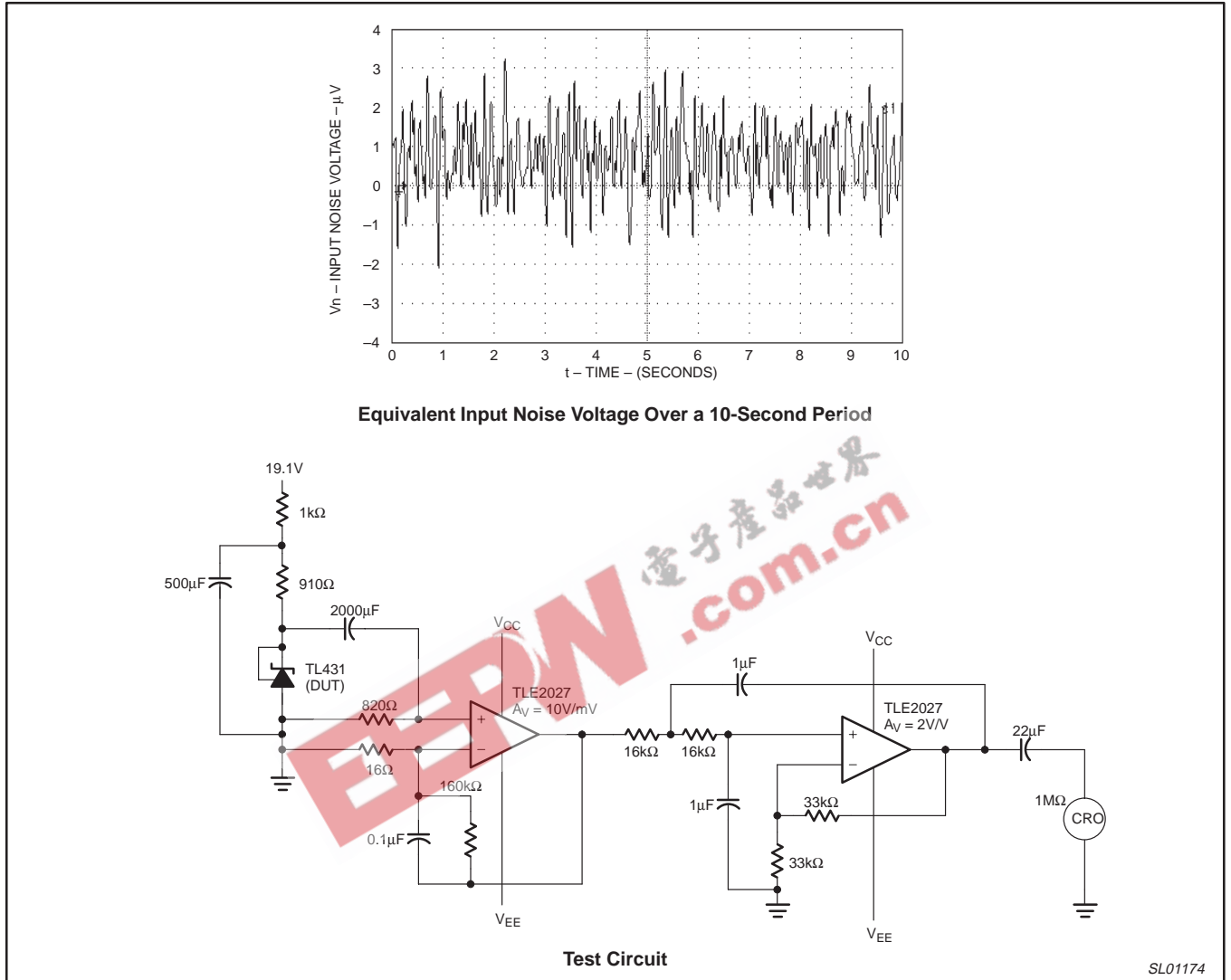


Figure 12.

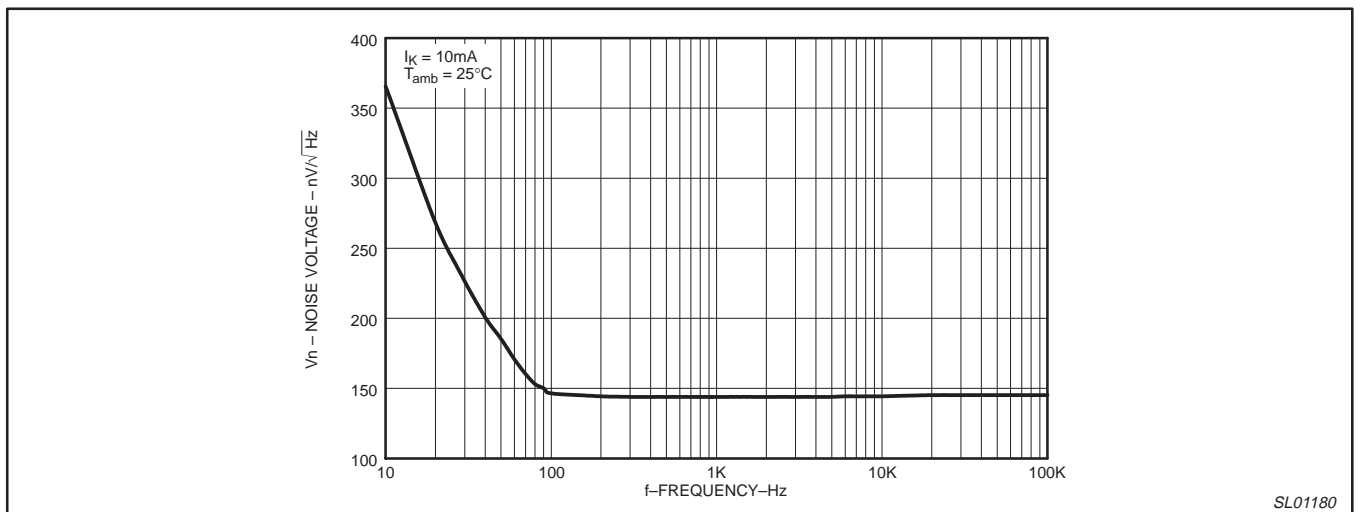


Figure 13. Equivalent Input Noise Voltage vs. Frequency

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

TYPICAL CHARACTERISTICS

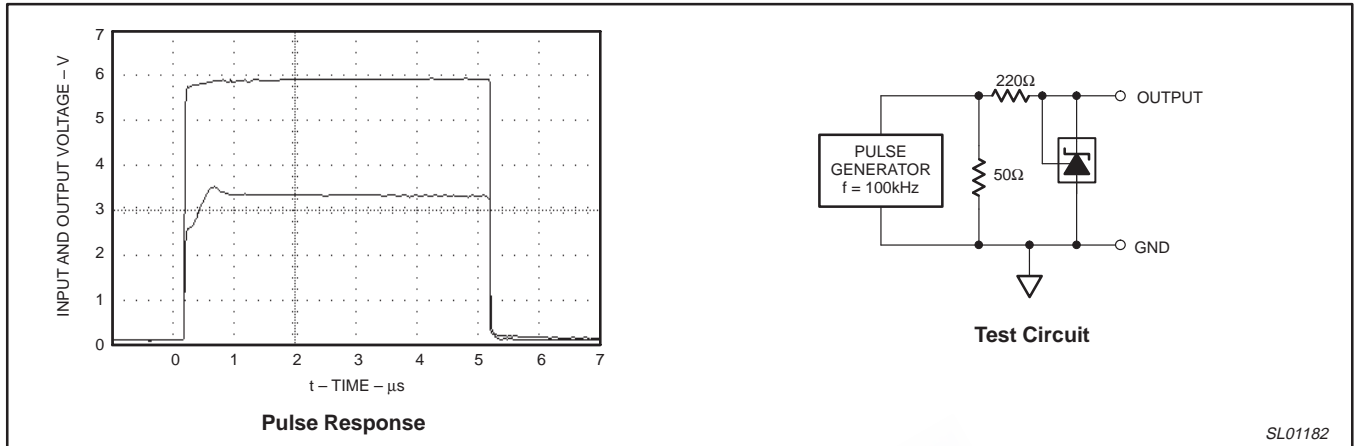


Figure 14. Pulse Response

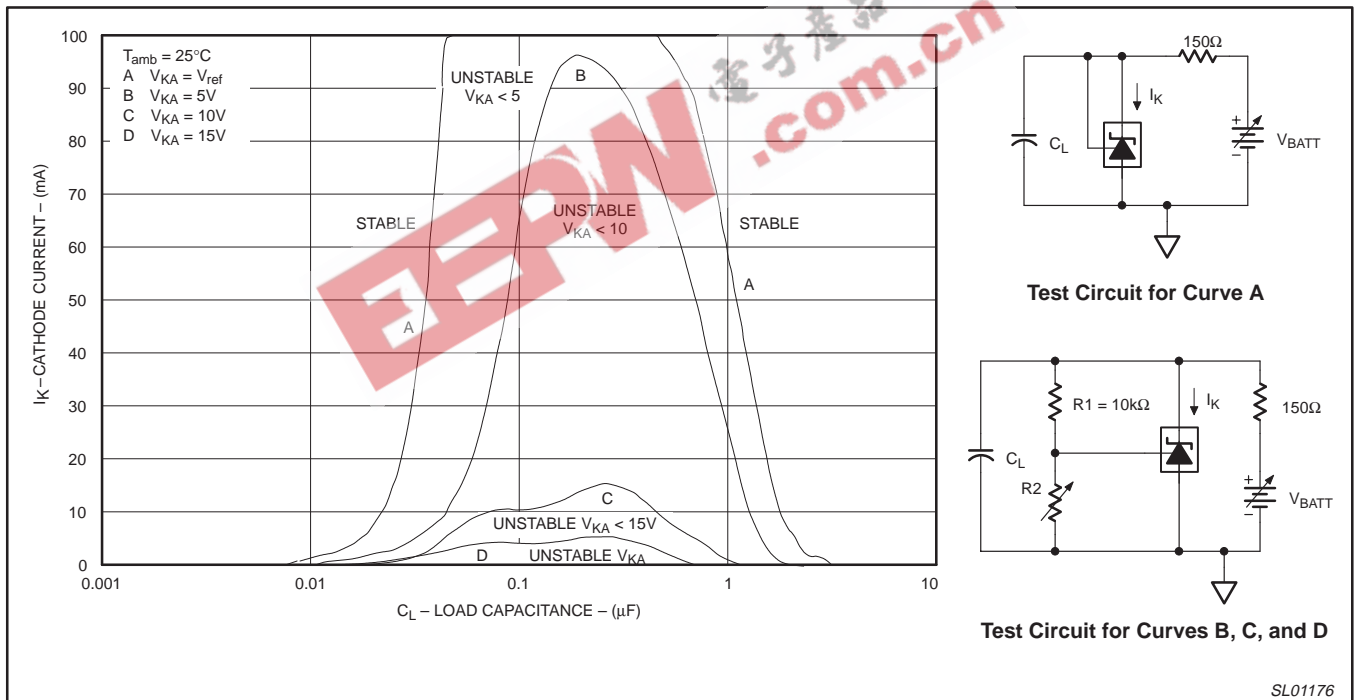


Figure 15. Stability Boundary Conditions

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TL431C, TL431AC, TL431I,
TL431AI, LM431AC

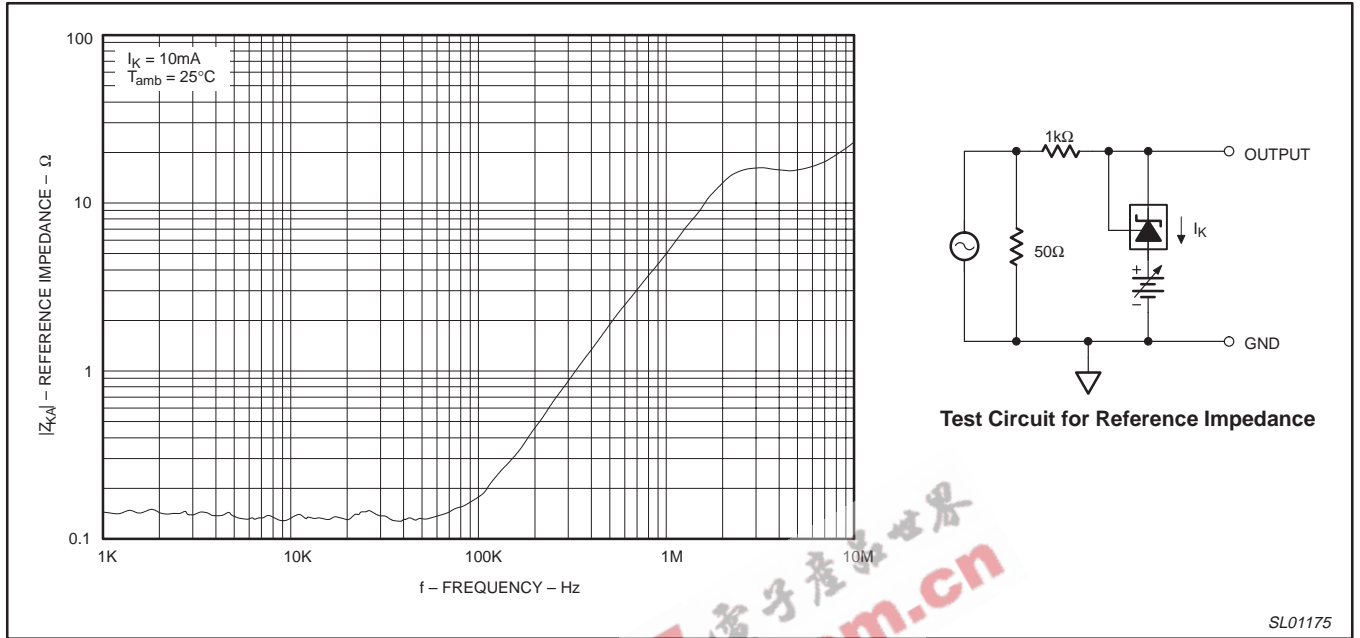


Figure 16. Reference Impedance vs. Frequency

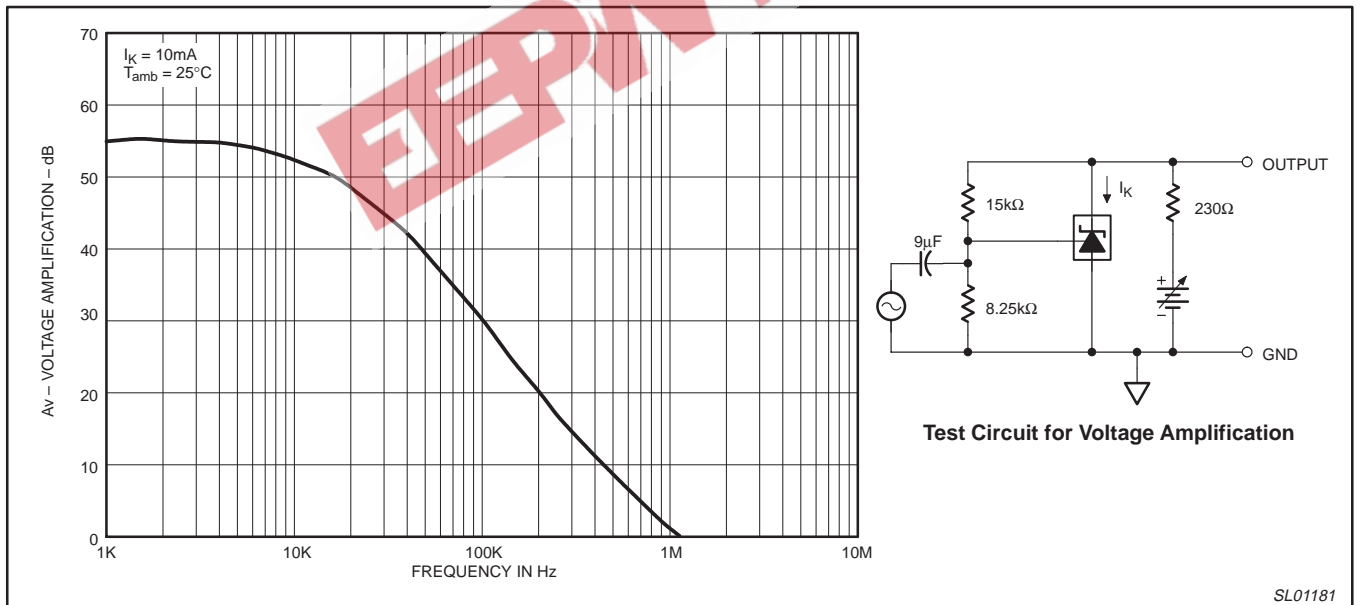


Figure 17. Small-Signal Voltage Amplification vs. Frequency

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I, TL431AI, LM431AC

TYPICAL APPLICATIONS

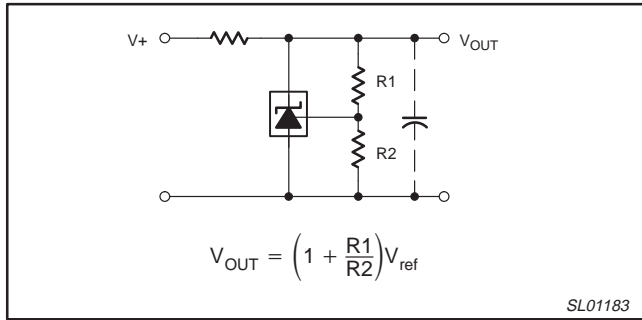


Figure 18. Shunt Regulator

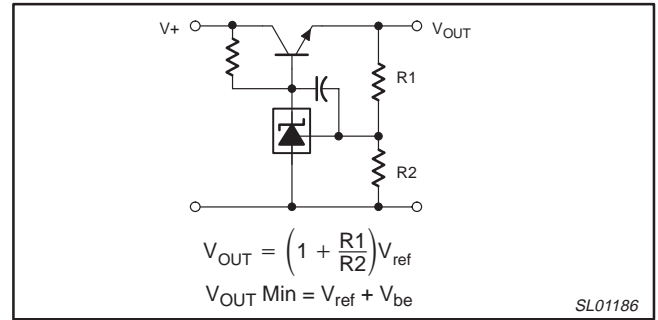


Figure 21. Series Pass Regulator

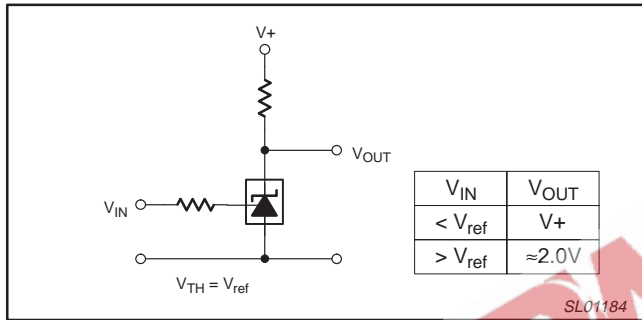


Figure 19. Single-Supply Comparator with Temperature-Compensated Threshold

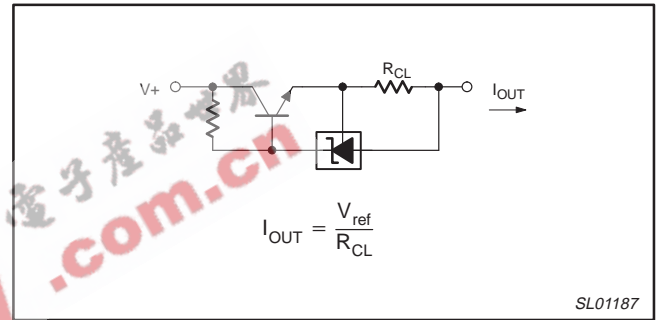


Figure 22. Constant Current Source

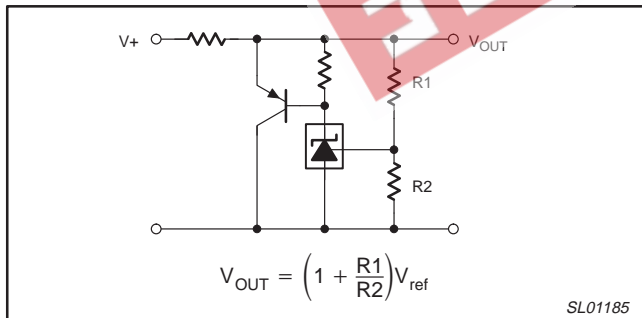


Figure 20. High Current Shunt Regulator

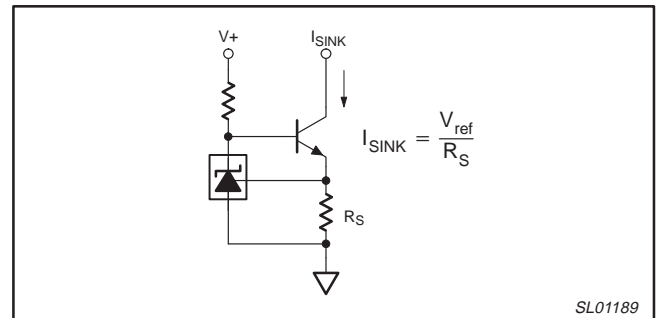


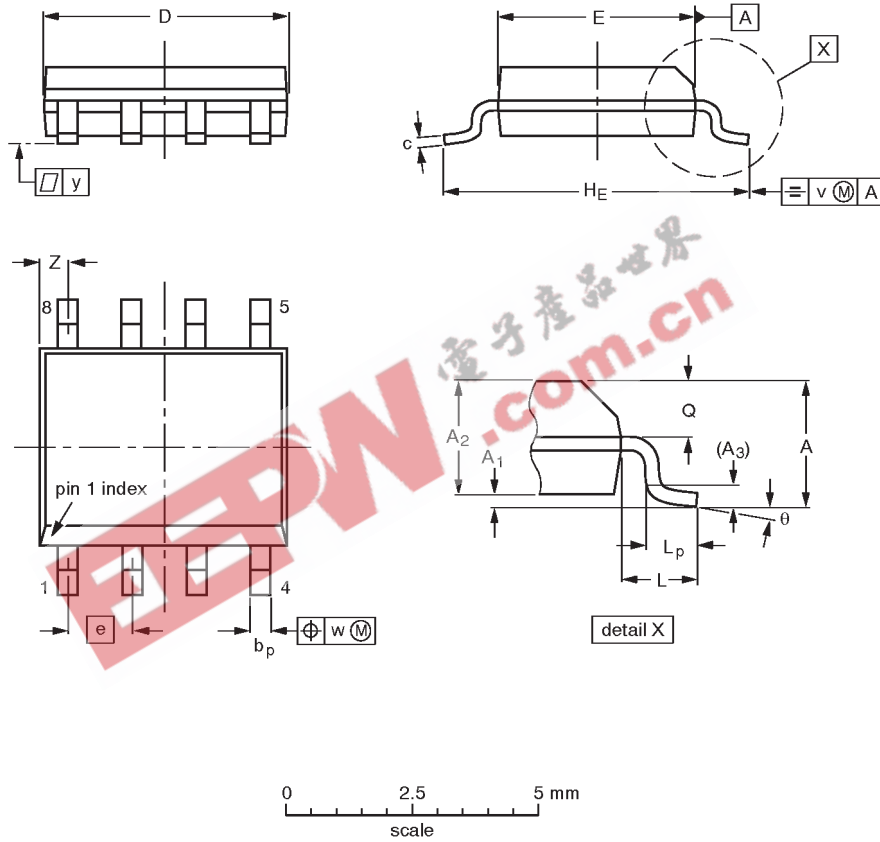
Figure 23. Constant Current Sink

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S08: plastic small outline package; 8 leads; body width 3.9mm

SOT96-1



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

| UNIT | A max. | A ₁ | A ₂ | A ₃ | b _p | c | D ⁽¹⁾ | E ⁽²⁾ | e | H _E | L | L _p | Q | v | w | y | Z ⁽¹⁾ | θ |
|--------|--------|------------------|----------------|----------------|----------------|------------------|------------------|------------------|-------|----------------|-------|----------------|----------------|------|------|-------|------------------|----------|
| mm | 1.75 | 0.25 0.10 | 1.45 1.25 | 0.25 | 0.49 0.36 | 0.25 0.19 | 5.0 4.8 | 4.0 3.8 | 1.27 | 6.2 5.8 | 1.05 | 1.0 0.4 | 0.7 0.6 | 0.25 | 0.25 | 0.1 | 0.7 0.3 | 8° 0° |
| inches | 0.069 | 0.0098 0.0039 | 0.057 0.049 | 0.01 | 0.019 0.014 | 0.0098 0.0075 | 0.20 0.19 | 0.16 0.15 | 0.050 | 0.24 0.23 | 0.041 | 0.039 0.016 | 0.028 0.024 | 0.01 | 0.01 | 0.004 | 0.028 0.012 | |

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

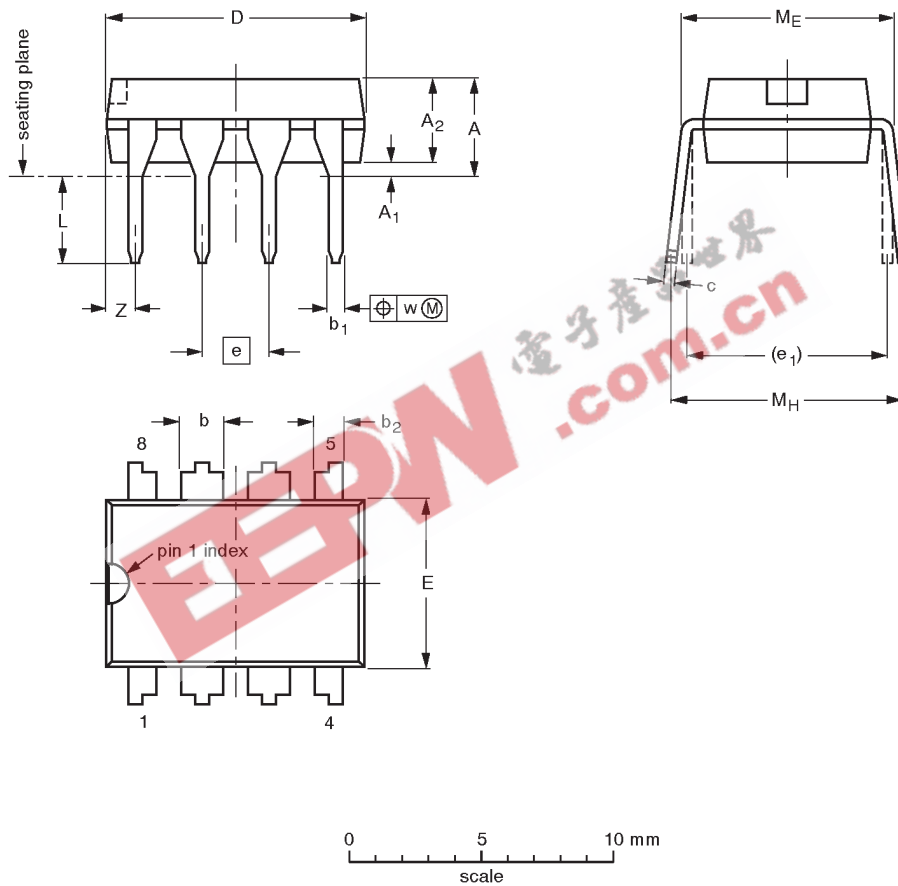
| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|-----------------|------------|----------|------|--|---------------------|----------------------|
| | IEC | JEDEC | EIAJ | | | |
| SOT96-1 | 076E03S | MS-012AA | | | | 92-11-17 95-02-04 |

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

DIP8: plastic dual in-line package; 8 leads (300 mil)

SOT97-1



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

| UNIT | A max. | A ₁ min. | A ₂ max. | b | b ₁ | b ₂ | c | D ⁽¹⁾ | E ⁽¹⁾ | e | e ₁ | L | M _E | M _H | w | Z ⁽¹⁾ max. |
|--------|--------|---------------------|---------------------|----------------|----------------|----------------|----------------|------------------|------------------|------|----------------|--------------|----------------|----------------|-------|-----------------------|
| mm | 4.2 | 0.51 | 3.2 | 1.73 1.14 | 0.53 0.38 | 1.07 0.89 | 0.36 0.23 | 9.8 9.2 | 6.48 6.20 | 2.54 | 7.62 | 3.60 3.05 | 8.25 7.80 | 10.0 8.3 | 0.254 | 1.15 |
| inches | 0.17 | 0.020 | 0.13 | 0.068 0.045 | 0.021 0.015 | 0.042 0.035 | 0.014 0.009 | 0.39 0.36 | 0.26 0.24 | 0.10 | 0.30 | 0.14 0.12 | 0.32 0.31 | 0.39 0.33 | 0.01 | 0.045 |

Note

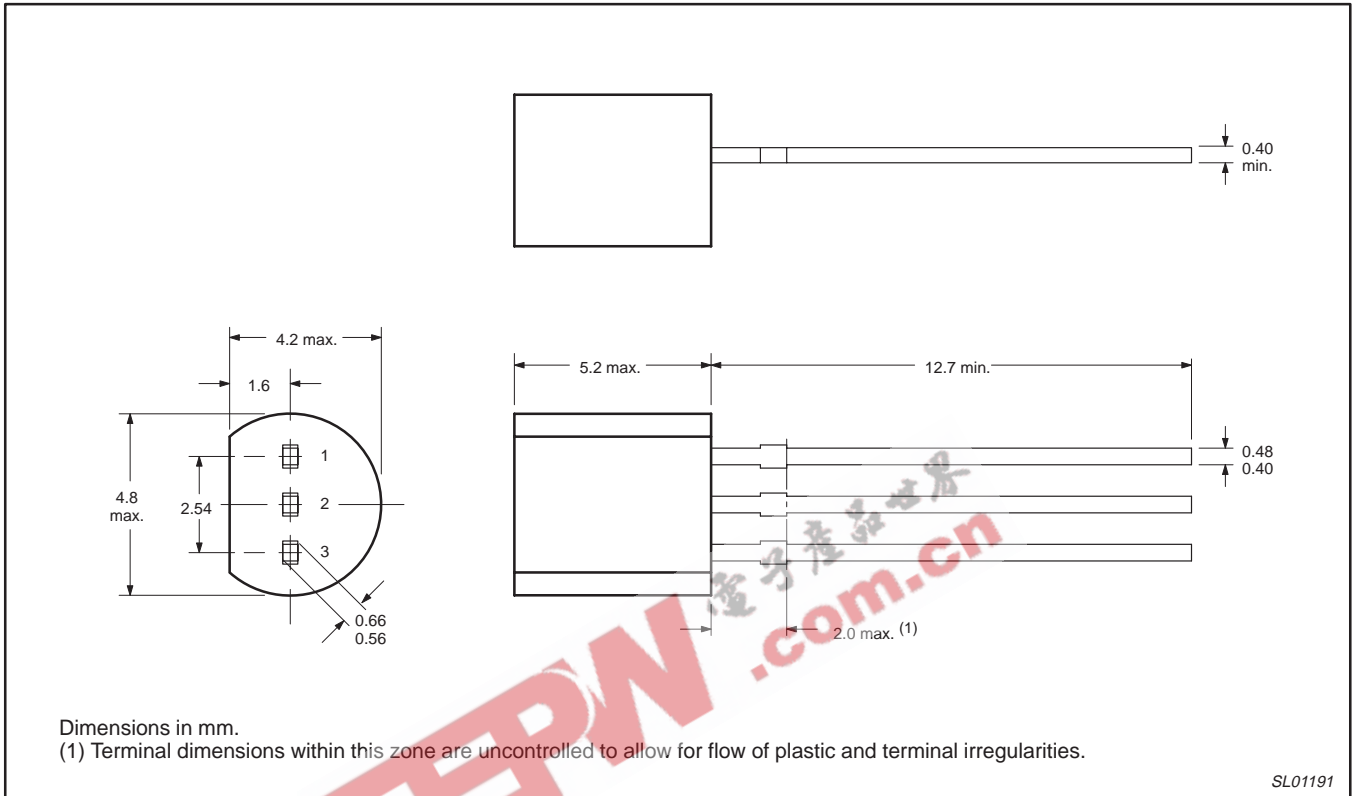
1. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

| OUTLINE VERSION | REFERENCES | | | | EUROPEAN PROJECTION | ISSUE DATE |
|-----------------|------------|----------|------|--|---------------------|----------------------|
| | IEC | JEDEC | EIAJ | | | |
| SOT97-1 | 050G01 | MO-001AN | | | | 92-11-17 95-02-04 |

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

SOT54



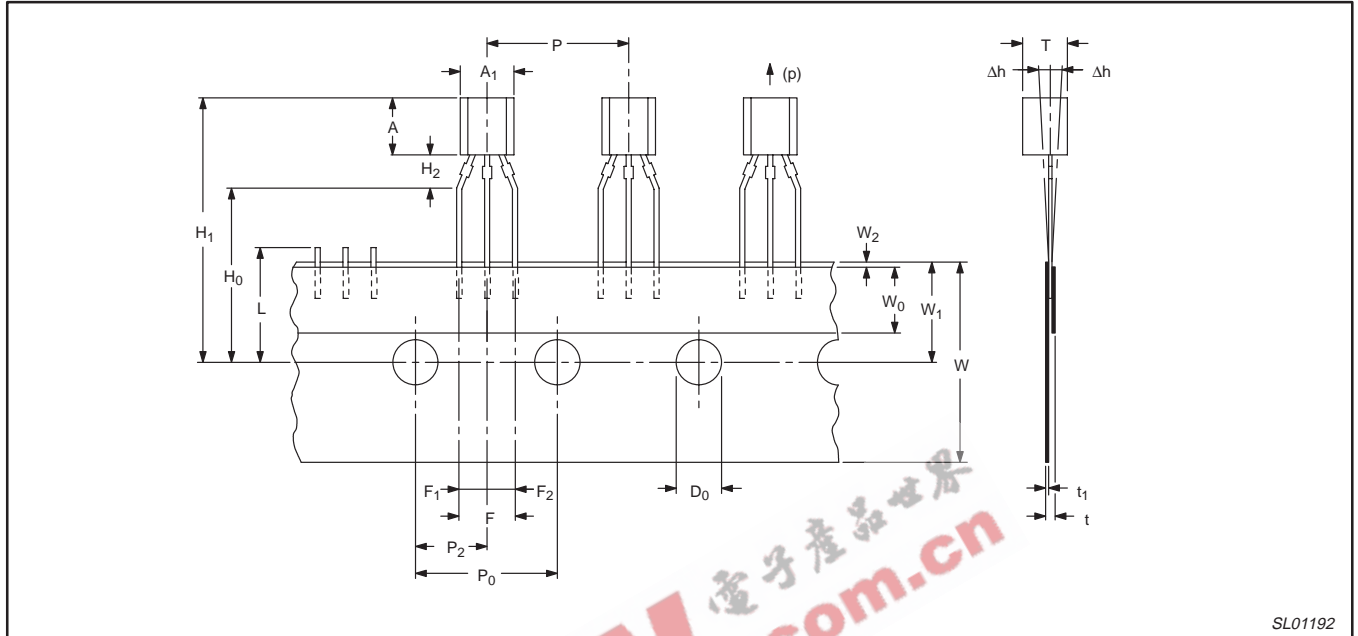
SL01191

Adjustable precision shunt regulators

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TO-92 transistors on tape

TO-92



SL01192

Table 2. Tape specification (TO-92 leaded types)

| SYMBOL | DIMENSION | SPECIFICATIONS | | | | | REMARKS |
|---------------------------------|--------------------------------------|----------------|------|-------|-----------|------|------------------------------------|
| | | MIN. | NOM. | MAX. | TOL. | UNIT | |
| A ₁ | Body width | 4 | – | 4.8 | – | mm | |
| A | Body height | 4.8 | | 5.2 | – | mm | |
| T | Body thickness | 3.5 | | 3.9 | – | mm | |
| P | Pitch of component | – | 12.7 | – | ±1 | mm | |
| P ₀ | Feed hole pitch | – | 12.7 | – | ±0.3 | mm | |
| | Cumulative pitch error | – | – | – | ±0.1 | mm | Note 1 |
| P ₂ | Feed hole center to component center | – | 6.35 | – | ±0.4 | mm | to be measured at bottom of clinch |
| F | Distance between outer leads | – | 5.08 | – | +0.6/–0.2 | mm | |
| Δh | Component alignment | – | 0 | 1 | – | mm | |
| W | Tape width | – | 18 | – | ±0.5 | mm | |
| W ₀ | Hold-down tape width | – | 6 | – | ±0.2 | mm | |
| W ₁ | Hole position | – | 9 | – | +0.7/–0.5 | mm | |
| W ₂ | Hold-down tape position | – | 0.5 | – | ±0.2 | mm | |
| H ₀ | Lead wire clinch height | – | 16.5 | – | ±0.5 | mm | |
| H ₁ | Component height | – | – | 23.25 | – | mm | |
| L | Length of snipped leads | – | – | 11 | – | mm | |
| D ₀ | Feed hole diameter | – | 4 | – | ±0.2 | mm | |
| t | Total tape thickness | – | – | 1.2 | – | mm | |
| F ₁ , F ₂ | Lead-to-lead distance | – | – | – | +0.4/–0.2 | mm | |
| H ₂ | Clinch height | – | – | – | – | mm | |
| (p) | Pull-out force | 6 | – | – | – | N | |

NOTE:

1. Measured over 20 devices.

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TL431C, TL431AC, TL431I, TL431AI, LM431AC

Tape splicing

Splice the carrier tape on the back and/or front so that the feed hole pitch (P_0) is maintained.

Bulk packing

In addition to TO-92 on tape, TO-92 can also be delivered in bulk. Products are packed in boxes in foil and plastic bags with 1,000 pieces to a bag and 5 bags to a box.

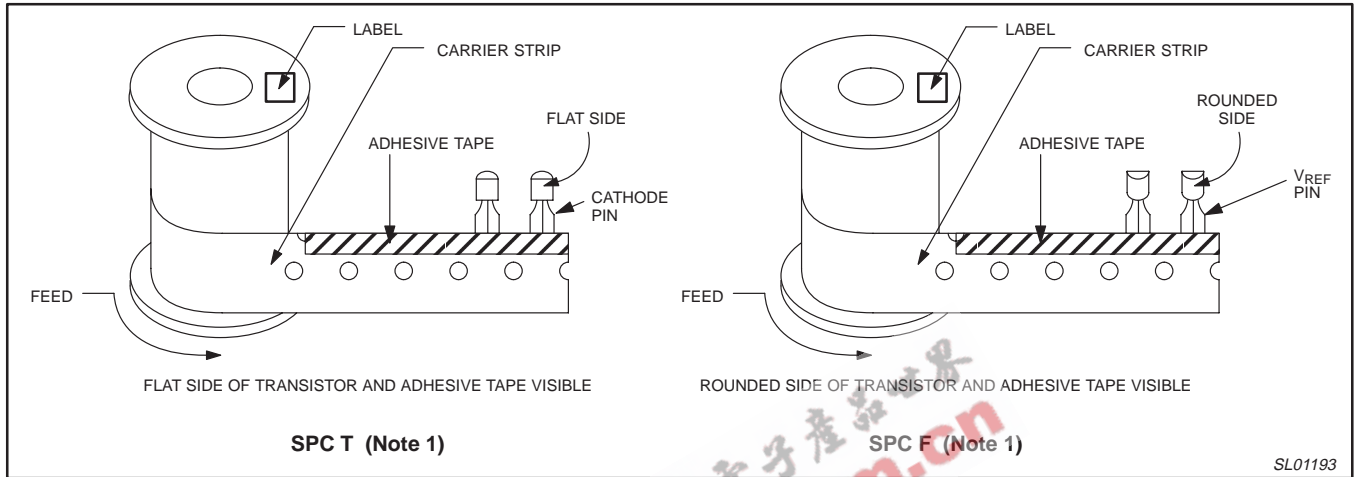
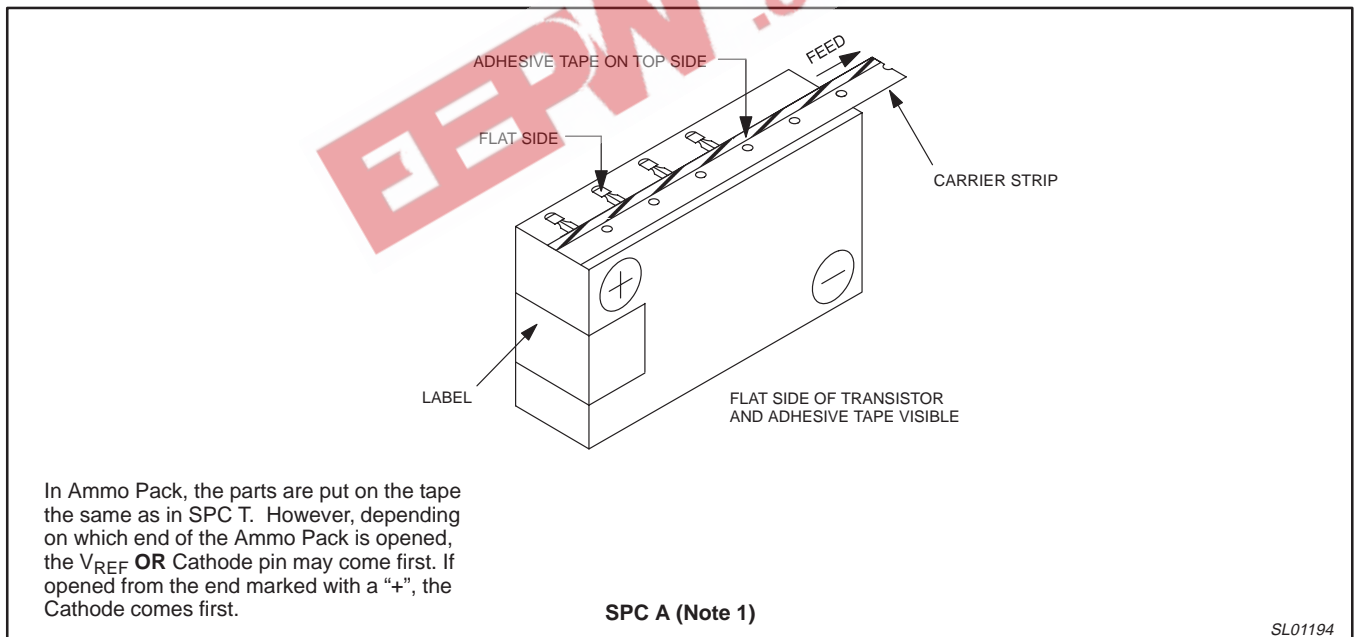


Figure 24. TO-92 Reel Styles



SPC A (Note 1)

Figure 25. TO-92 Ammo Pack Styles

NOTE:

1. Order SPC F, T or A depending on what is required.

Adjustable precision shunt regulators

TL431C, TL431AC, TL431I,
TL431AI, LM431AC

DEFINITIONS

| Data Sheet Identification | Product Status | Definition |
|----------------------------------|-------------------------------|--|
| <i>Objective Specification</i> | Formative or in Design | This data sheet contains the design target or goal specifications for product development. Specifications may change in any manner without notice. |
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